

# PATENT SPECIFICATION

DRAWINGS ATTACHED

1 206 007



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## (54) DEVICES FOR SEPARATING A LIQUID AND/OR A VAPOUR FROM A FLOWING CARRIER GAS STREAM

(71) We, THE SWISS CONFEDERATION, represented by THE FEDERAL MINISTER OF DEFENCE, of Berne, Switzerland, do hereby declare the invention for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to devices for separating a liquid and/or a vapour from a flowing carrier gas stream.

According to the present invention there is provided a device for separating a liquid and/or vapour from a flowing carrier gas stream, comprising first means to produce a shock-like change in pressure in the gas stream with consequent temperature drop and supercooling, the first means including a net or grid through which the gas stream passes, and second means downstream of the first means to remove droplets of liquid from the gas stream.

Such devices are suitable for use in air conditioning plants, and particularly, but by no means exclusively, in such plants in aircraft.

Embodiments of the invention will now be described by way of example with reference to the accompanying drawings, in which:—

Fig. 1 is an elevation of a device for water separation,

Fig. 2 is a longitudinal section of the device shown in Fig. 1,

Fig. 3 is an enlarged side view of a screw of the device shown in Fig. 2,

Figs. 4 and 5 are longitudinal section and a rear view of another form of water separator.

Referring to Fig. 1 the device, which will be assumed to form part of an air conditioning plant, has the external shape of a cylindrical tube 1 having an open end 2 through which flows the incoming moisture-bearing cold air, in the direction indicated by the arrow, and an open end 9 through which flows the outgoing moisture-free air in the direction indicated by the arrow. The tube 1

also has a collar-like flaring 14 in which the separated water is collected and to which is connected a conduit 15 to draw off the collected water. The tube 1 is connected by the end 2 to the outlet orifice of a gas or air cooler (not shown). The outlet end 9 is connected to one or more further conduits (not shown), through which the cold and for the most part water-free air is led to the desired outflow points. The tubular water separator illustrated in Fig. 1 therefore represents a part of the air conduit extending from the cooler to the place where the conditioned air is used. As in most cases it is not desirable or is not possible to install the cooler directly at the place at which the conditioned air is used, a connecting conduit must in any case be provided. The device illustrated replaces this connecting conduit either partially or completely so that advantageously it requires no additional space.

Further details of the device illustrated by way of example in Fig. 1 are described hereinafter with reference to Figs. 2 and 3. Adjacent the open end of the tube 1 through which flows the incoming vapour-bearing cold air is a straight tube section 3 in which the formation of a condensate from the vapour is brought about. Then follows a tube section 4 which may have a slight bend and which is provided as a flow section for the water droplet-air mixture in the case that the tube 1 cannot extend in a straight line over its whole length for reasons of space. However the tube section 4 can also be omitted. The length of the section 4 and the bend thereof are consequently completely irrelevant with regard to the function of the device.

The tube section 4 which may be provided can be releasably connected by means of couplings to the tube section 3 and the tube section 5 so that the sections 3 on the one hand and 5 to 8 on the other hand which belong to the device proper can form completely separated units. Even if there is no tube section 4, the tube sections 3 and 5 can

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be releasably joined together by means of a coupling.

Following the tube section 4, there is provided a straight tube section 5 in which a rotation about the flow axis, which rotation becomes continuously faster in the downstream direction, is superimposed on the axially flowing mixture so that as a result of their greater centrifugal force the heavy water droplets are urged against the wall of the tube 1 in a subsequent straight line tube section 6 provided to act as a diffuser section, while the air tends to move in a more axial direction. The optimum length of the diffuser section lies in the range of from 1 to 2 times the internal diameter of this tube portion. In the subsequent tube section 7 the separated water droplets are for the most part removed and drawn off through the conduit 15.

A further straight tube section 8 serves continuously to eliminate the remaining components of the rapid rotation of the on-wardly flowing air so that at the outlet-side end 9 of the tube 1 there only remains an at least approximately axial air flow component. The same effect can be achieved by providing an evolute 17 instead of the tube section 8, the air being lead off tangentially and perpendicularly to the preceding tube section, as illustrated in Figs. 4 and 5.

An element 10 comprising a fine-mesh net of thin metal wires and supporting sheet metal ribs is arranged in the tube section 3. This is provided to remove as large a portion as possible of the vapour present in the incoming cooled air. More importantly, the shock pressure change associated with the passage of the gas through the net results in a temperature drop and supercooling of the air, which causes the formation of water droplets. It is therefore, e.g., possible to use a net comprising rust proof steel wire as a so-called condensation grid and possibly to combine this with a further catalyst e.g. with silver iodide. The element 10 advantageously has the shape of the surface of a cone, the axis of which lies in the axis of flow and the point of which is directed in opposition to the flow. The base area of the cone approximately corresponds in this case to the cross section of the tube 1. The element 10 can be constructed so as to be supported by a self-supporting network and/or by sheet metal ribs, being inserted into the tube 1 and secured displacement at the desired point for example by stops such as rivet pins.

The element arranged in the tube section 5 which produces the rotation of the air flow comprises a rigidly installed one-part screw 11 comprising a single workpiece. The two faces of the screws 11 form together with the cylindrical wall of the tube 1 two screw-shaped channels through which the air flows

and which consequently impart to the air flow the desired swirl.

The screw 11 is of such a shape that its pitch in the flow direction progressively and continually decreases from an almost infinitely large value to a very small value. This provides that the air flow is turned successively so that pressure losses due to breakdown of the flow are avoided.

Fig. 3 shows an enlarged side view of the screw 11 shown in diagrammatic form in Fig. 2. The screw 11 is half a pitch in length and is sharp at its inlet edge 11<sup>1</sup> and/or its outlet edge. It can be milled for example by means of a programme controlled milling machine from solid material or it can be produced by twisting a metal strip in a clamping device which provides the desired progressive pitch. The screw 11 overwound to the internal diameter of the tube 1 (Fig. 2) is inserted into the tube 1 and secured against displacement and rotation at the point intended (tube section 5) for example by means of rivet pins inserted into the tube.

In the wall of the tube 1 in the tube section 7 there are arranged slots 13 overlapping in the direction of flow and extending obliquely, approximately transversely of the resultant flow direction prevailing at the wall. In addition the tube section 7 is enclosed by an external jacket 14, the inner wall of which defines together with the outer wall of the tube 1 an annular chamber. The water droplets passing from the tube section 6 along the inner wall of the tube 1 pass outwardly through the slots 13 and are collected by the jacket 14, whereupon they pass into the open through the downwardly leading conduit 15. The conduit 15 has a restriction 16 which acts as a throttle for the air passing through the slots 13 into the jacket 14 with the water droplets and thereby keeps the loss of air low. The jacket is with advantage eccentric with respect to the gas tube.

Arranged in the last tube section 8 is an element which eliminates the rotation of the air flow and which also comprises a rigidly mounted screw 12 which is of identical construction to the screw 11, but is reversed end for end so that in the direction of flow the pitch progressively increases from a very small value to a very large value.

The straight tube section 8 and the screw 12 arranged therein can also be replaced by an evolute 17 as illustrated in Figs. 4 and 5. The evolute 17 is an eccentrically arranged collecting chamber which eliminates the rotation of the on-wardly flowing air in that the air is collected in a convex bend of increasing cross section and after almost one circuit is lead off tangentially to the tube, perpendicularly to the original flow axis.

Associated with the new velocity components resulting from the generation of the rotation in the section 5 is a fall in the static

pressure in the flow. When the rotation is eliminated in the tube section 8 or in the evolute 17 this pressure fall is for the most part recuperated, whereby the pressure loss measurable in the whole device between the inlet 2 and the outlet 9 is substantially reduced.

The inlet end 2 and the outlet end 9 of the tube 1 have the same diameter as the preceding or following conduit of the air conditioning system. The tube sections 3, 4, 5, 6, 7 and 8 are of the same diameter or are only immaterially larger than these conduits. The length of the device from the end 2 to the end 9 is, excluding the tube section 4 but including the tube section 8, approximately ten times greater than the tube diameter. The tube section 4, as already mentioned, can be straight or also bent and may be of any length. These properties of the device, together with the fact that in most cases a certain length of piping is necessary between the cooler and the space to be provided with conditioned air, ensure that the additional space required for the water separator remains limited to the additional space required for the tube section 7, i.e. to the space required for the jacket 14 and the conduit 15 and possibly for the evolute 17. As the wall of the tube sections 3, 4, 5, 6, 7 and 8 corresponds to the conduit wall normally used in any case, the increase in weight of the device in comparison with a simple conduit only consists of the weight of the net-shaped and supported element 10, the two screws 11 and 12, the jacket 14 and the drainpipe 15, which represents only an immaterial weight increase. Finally the device described has the advantages that the efficiency of the water separation is relatively high, i.e. for example 60%, that the means provided for this purpose can be produced in a simple manner and without particularly high costs, and that in addition the device requires practically no maintenance as there are neither moving parts nor non-metallic material.

So that the air cooled in the cooler mounted upstream of the water separator cannot heat up again to a too great a degree in the region of the water separator, it is of advantage for the tube 1 (Fig. 2) to be enclosed by an insulating layer 18.

#### WHAT WE CLAIM IS:—

1. A device for separating a liquid and/or a vapour from a flowing carrier gas stream, comprising first means to produce a shock-like change in pressure in the gas stream with consequent temperature drop and supercooling, the first means including a net or grid through which the gas stream passes, and second means downstream of the first means to remove droplets of liquid from the gas stream.

2. A device according to claim 1 wherein the first means comprises a net or grid in the

shape of a cone disposed in the path of the gas stream with the apex of the cone upstream.

3. A device according to claim 2 wherein the net or grid is made of rust-proof wire.

4. A device according to claim 3 wherein the cone is reinforced by internal ribs.

5. A device according to any one of the preceding claims wherein the first means further includes a material which promotes droplet formation.

6. A device according to claim 5 wherein said material is silver iodide.

7. A device according to any one of the preceding claims wherein the second means includes a swirl member disposed in the path of the gas stream to give a radial component of velocity to the gas stream.

8. A device according to claim 7 wherein the swirl member is metal and is formed by, or shaped like, a strip twisted into a helix.

9. A device according to claim 8 wherein the pitch of the helix decreases continuously in the downstream direction.

10. A device according to claim 9 wherein the pitch of the helix at the upstream end is infinite.

11. A device according to claim 8, claim 9 or claim 10 wherein the helix is approximately half a pitch long.

12. A device according to any one of claims 8 to 11 wherein a second swirl member is disposed in the path of the gas stream downstream of the second means, to cancel said radial component of velocity.

13. A device according to claim 12 wherein the second swirl member is substantially identical to the first-mentioned swirl member, but is reversed end for end.

14. A device according to any one of claims 8 to 11 wherein an evolute is disposed in the path of the gas stream downstream of the second means.

15. A device according to any one of claims 7 to 14 wherein the second means further includes a diffuser downstream of the first-mentioned swirl member, to remove droplets of liquid from the gas stream.

16. A device according to claim 15 wherein the diffuser comprises a tubular member through which the gas stream passes, the walls of the tubular member being slotted so that droplets of liquid can pass through the walls.

17. A device according to claim 16 wherein the tubular member is encircled by an annular chamber in which the droplets of liquid passing through the slotted walls are collected.

18. A device according to claim 16 or claim 17 wherein the tubular member is of circular cross-section, and of a length one to two times the diameter.

19. A device according to any one of the preceding claims made up of a plurality of

tubular sections suitably secured together.

20. A device according to claim 19 of straight tubular shape.

5 21. A device according to any one of the preceding claims wherein the structural parts are made entirely of metal.

10 22. A device according to any one of the preceding claims wherein at least part of the exterior of the device has a layer of thermally-insulating material.

23. In an air conditioning plant a device according to any one of the preceding claims.

15 24. In an aircraft air conditioning plant a device according to any one of claims 1 to 22.

25. A device for separating a liquid and/or a vapour from a flowing carrier gas stream, the device being substantially as hereinbefore described with reference to Figs. 1 to 3.

20 26. A device for separating a liquid and/or a vapour from a flowing carrier gas stream, the device being substantially as hereinbefore described with reference to Figs. 4 and 5.

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Fig. 1

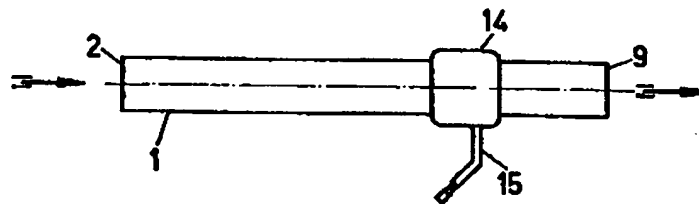


Fig. 2

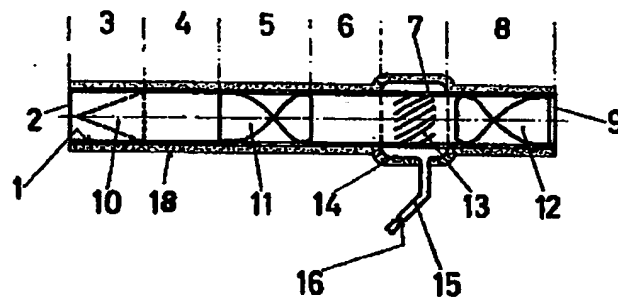


Fig. 3

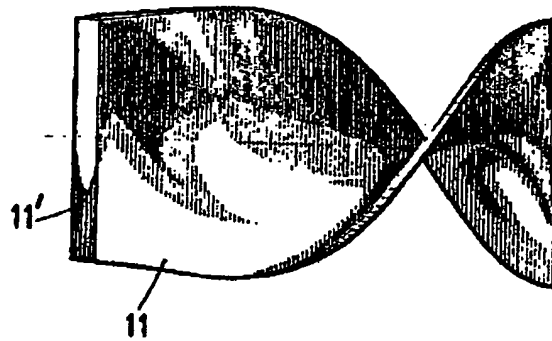


Fig. 5

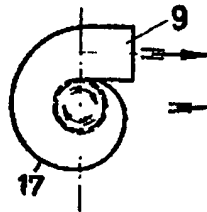
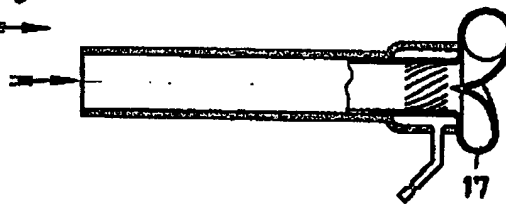


Fig. 4



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also has a collar-like flaring 14 in which the separated water is collected and to which is connected a conduit 15 to draw off the collected water. The tube 1 is connected by the end 2 to the outlet orifice of a gas or air cooler (not shown). The outlet end 9 is connected to one or more further conduits (not shown), through which the cold and for the most part water-free air is led to the desired outflow points. The tubular water separator illustrated in Fig. 1 therefore represents a part of the air conduit extending from the cooler to the place where the conditioned air is used. As in most cases it is not desirable or is not possible to install the cooler directly at the place at which the conditioned air is used, a connecting conduit must in any case be provided. The device illustrated replaces this connecting conduit either partially or completely so that advantageously it requires no additional space.

Further details of the device illustrated by way of example in Fig. 1 are described hereinafter with reference to Figs. 2 and 3. Adjacent the open end of the tube 1 through which flows the incoming vapour-bearing cold air is a straight tube section 3 in which the formation of a condensate from the vapour is brought about. Then follows a tube section 4 which may have a slight bend and which is provided as a flow section for the water droplet-air mixture in the case that the tube 1 cannot extend in a straight line over its whole length for reasons of space. However the tube section 4 can also be omitted. The length of the section 4 and the bend thereof are consequently completely irrelevant with regard to the function of the device.

The tube section 4 which may be provided can be releasably connected by means of couplings to the tube section 3 and the tube section 5 so that the sections 3 on the one hand and 5 to 8 on the other hand which belong to the device proper can form completely separated units. Even if there is no tube section 4, the tube sections 3 and 5 can

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be releasably joined together by means of a coupling.

Following the tube section 4, there is provided a straight tube section 5 in which a rotation about the flow axis, which rotation becomes continuously faster in the downstream direction, is superimposed on the axially flowing mixture so that as a result of their greater centrifugal force the heavy water droplets are urged against the wall of the tube 1 in a subsequent straight line tube section 6 provided to act as a diffuser section, while the air tends to move in a more axial direction. The optimum length of the diffuser section lies in the range of from 1 to 2 times the internal diameter of this tube portion. In the subsequent tube section 7 the separated water droplets are for the most part removed and drawn off through the conduit 15.

A further straight tube section 8 serves continuously to eliminate the remaining components of the rapid rotation of the onwardly flowing air so that at the outlet-side end 9 of the tube 1 there only remains an at least approximately axial air flow component. The same effect can be achieved by providing an evolute 17 instead of the tube section 8, the air being lead off tangentially and perpendicularly to the preceding tube section, as illustrated in Figs. 4 and 5.

An element 10 comprising a fine-mesh net of thin metal wires and supporting sheet metal ribs is arranged in the tube section 3. This is provided to remove as large a portion as possible of the vapour present in the incoming cooled air. More importantly, the shock pressure change associated with the passage of the gas through the net results in a temperature drop and supercooling of the air, which causes the formation of water droplets. It is therefore, e.g., possible to use a net comprising rust proof steel wire as a so-called condensation grid and possibly to combine this with a further catalyst e.g. with silver iodide. The element 10 advantageously has the shape of the surface of a cone, the axis of which lies in the axis of flow and the point of which is directed in opposition to the flow. The base area of the cone approximately corresponds in this case to the cross section of the tube 1. The element 10 can be constructed so as to be supported by a self-supporting network and/or by sheet metal ribs, being inserted into the tube 1 and secured displacement at the desired point for example by stops such as rivet pins.

The element arranged in the tube section 5 which produces the rotation of the air flow comprises a rigidly installed one-part screw 11 comprising a single workpiece. The two faces of the screws 11 form together with the cylindrical wall of the tube 1 two screw-shaped channels through which the air flows

and which consequently impart to the air flow the desired swirl.

The screw 11 is of such a shape that its pitch in the flow direction progressively and continually decreases from an almost infinitely large value to a very small value. This provides that the air flow is turned successively so that pressure losses due to breakdown of the flow are avoided.

Fig. 3 shows an enlarged side view of the screw 11 shown in diagrammatic form in Fig. 2. The screw 11 is half a pitch in length and is sharp at its inlet edge 11' and/or its outlet edge. It can be milled for example by means of a programme controlled milling machine from solid material or it can be produced by twisting a metal strip in a clamping device which provides the desired progressive pitch. The screw 11 overwound to the internal diameter of the tube 1 (Fig. 2) is inserted into the tube 1 and secured against displacement and rotation at the point intended (tube section 5) for example by means of rivet pins inserted into the tube.

In the wall of the tube 1 in the tube section 7 there are arranged slots 13 overlapping in the direction of flow and extending obliquely, approximately transversely of the resultant flow direction prevailing at the wall. In addition the tube section 7 is enclosed by an external jacket 14, the inner wall of which defines together with the outer wall of the tube 1 an annular chamber. The water droplets passing from the tube section 6 along the inner wall of the tube 1 pass outwardly through the slots 13 and are collected by the jacket 14, whereupon they pass into the open through the downwardly leading conduit 15. The conduit 15 has a restriction 16 which acts as a throttle for the air passing through the slots 13 into the jacket 14 with the water droplets and thereby keeps the loss of air low. The jacket is with advantage eccentric with respect to the gas tube.

Arranged in the last tube section 8 is an element which eliminates the rotation of the air flow and which also comprises a rigidly mounted screw 12 which is of identical construction to the screw 11, but is reversed end for end so that in the direction of flow the pitch progressively increases from a very small value to a very large value.

The straight tube section 8 and the screw 12 arranged therein can also be replaced by an evolute 17 as illustrated in Figs. 4 and 5. The evolute 17 is an eccentrically arranged collecting chamber which eliminates the rotation of the onwardly flowing air in that the air is collected in a convex bend of increasing cross section and after almost one circuit is lead off tangentially to the tube, perpendicularly to the original flow axis.

Associated with the new velocity components resulting from the generation of the rotation in the section 5 is a fall in the static

pressure in the flow. When the rotation is eliminated in the tube section 8 or in the evolute 17 this pressure fall is for the most part recuperated, whereby the pressure loss measurable in the whole device between the inlet 2 and the outlet 9 is substantially reduced.

The inlet end 2 and the outlet end 9 of the tube 1 have the same diameter as the preceding or following conduit of the air conditioning system. The tube sections 3, 4, 5, 6, 7 and 8 are of the same diameter or are only immaterially larger than these conduits. The length of the device from the end 2 to the end 9 is, excluding the tube section 4 but including the tube section 8, approximately ten times greater than the tube diameter. The tube section 4, as already mentioned, can be straight or also bent and may be of any length. These properties of the device, together with the fact that in most cases a certain length of piping is necessary between the cooler and the space to be provided with conditioned air, ensure that the additional space required for the water separator remains limited to the additional space required for the tube section 7, i.e. to the space required for the jacket 14 and the conduit 15 and possibly for the evolute 17. As the wall of the tube sections 3, 4, 5, 6, 7 and 8 corresponds to the conduit wall normally used in any case, the increase in weight of the device in comparison with a simple conduit only consists of the weight of the net-shaped and supported element 10, the two screws 11 and 12, the jacket 14 and the drainpipe 15, which represents only an immaterial weight increase. Finally the device described has the advantages that the efficiency of the water separation is relatively high, i.e. for example 60%, that the means provided for this purpose can be produced in a simple manner and without particularly high costs, and that in addition the device requires practically no maintenance as there are neither moving parts nor non-metallic material.

So that the air cooled in the cooler mounted upstream of the water separator cannot heat up again to a too great a degree in the region of the water separator, it is of advantage for the tube 1 (Fig. 2) to be enclosed by an insulating layer 18.

#### WHAT WE CLAIM IS:—

1. A device for separating a liquid and/or a vapour from a flowing carrier gas stream, comprising first means to produce a shock-like change in pressure in the gas stream with consequent temperature drop and supercooling, the first means including a net or grid through which the gas stream passes, and second means downstream of the first means to remove droplets of liquid from the gas stream.

2. A device according to claim 1 wherein the first means comprises a net or grid in the

shape of a cone disposed in the path of the gas stream with the apex of the cone upstream.

3. A device according to claim 2 wherein the net or grid is made of rust-proof wire.

4. A device according to claim 3 wherein the cone is reinforced by internal ribs.

5. A device according to any one of the preceding claims wherein the first means further includes a material which promotes droplet formation.

6. A device according to claim 5 wherein said material is silver iodide.

7. A device according to any one of the preceding claims wherein the second means includes a swirl member disposed in the path of the gas stream to give a radial component of velocity to the gas stream.

8. A device according to claim 7 wherein the swirl member is metal and is formed by, or shaped like, a strip twisted into a helix.

9. A device according to claim 8 wherein the pitch of the helix decreases continuously in the downstream direction.

10. A device according to claim 9 wherein the pitch of the helix at the upstream end is infinite.

11. A device according to claim 8, claim 9 or claim 10 wherein the helix is approximately half a pitch long.

12. A device according to any one of claims 8 to 11 wherein a second swirl member is disposed in the path of the gas stream downstream of the second means, to cancel said radial component of velocity.

13. A device according to claim 12 wherein the second swirl member is substantially identical to the first-mentioned swirl member, but is reversed end for end.

14. A device according to any one of claims 8 to 11 wherein an evolute is disposed in the path of the gas stream downstream of the second means.

15. A device according to any one of claims 7 to 14 wherein the second means further includes a diffuser downstream of the first-mentioned swirl member, to remove droplets of liquid from the gas stream.

16. A device according to claim 15 wherein the diffuser comprises a tubular member through which the gas stream passes, the walls of the tubular member being slotted so that droplets of liquid can pass through the walls.

17. A device according to claim 16 wherein the tubular member is encircled by an annular chamber in which the droplets of liquid passing through the slotted walls are collected.

18. A device according to claim 16 or claim 17 wherein the tubular member is of circular cross-section, and of a length one to two times the diameter.

19. A device according to any one of the preceding claims made up of a plurality of

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Fig. 3

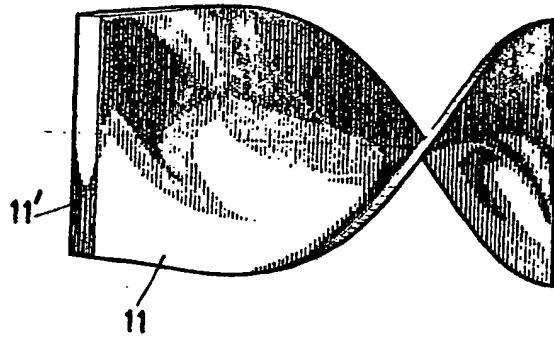


Fig. 5

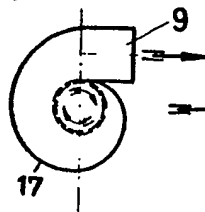


Fig. 4

